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Cloud Seeding Theory

Clouds form when temperatures in the atmosphere reach saturation, that is relative humidities of 100%. This saturated condition causes water vapor to condense around a nucleus forming a cloud droplet. These nuclei, which may be small particles like salts formed through evaporation off the oceans, are known as "cloud condensation nuclei." Clouds can be composed of water droplets, ice crystals or a combination of the two. Clouds that are entirely warmer than freezing are sometimes referred to as "warm clouds". Likewise, clouds that are colder than freezing are sometimes referred to as "cold clouds." Cold clouds may have cloud bases that are warmer than freezing. Precipitation can occur naturally from both types of clouds.

In warm clouds, cloud droplets that survive long enough and especially when cloud drops are of different sizes, may result in cloud water droplets colliding and growing that may reach raindrop sizes that can fall to the ground as rain. This process is known as "collision/coalescence." This process is especially important in tropical clouds but can also occur in more temperate climates.

In cold regions ($< 0^0$ C) of clouds, cloud water droplets may not freeze. The reason for this is the purity of the cloud water droplets. In a laboratory environment, pure water droplets can remain unfrozen down to a temperature of -39^0 F. Natural impurities in the atmosphere can cause cloud droplets that are colder than freezing (usually referred to as supercooled) to freeze. These supercooled cloud droplets are what causes icing to occur on aircraft. The natural impurities often consist of tiny soil particles or bacteria. These impurities are referred as "freezing nuclei." A supercooled cloud droplet can be frozen when it collides with one of these natural freezing nuclei thus forming an ice crystal. This process is known as "contact nucleation." A water droplet may also be formed on a freezing nucleus, which has hygroscopic (water attracting) characteristics. This same nucleus can then cause the water droplet to freeze at temperatures less than about -5^0 C forming an ice crystal. This process is known as "condensation/freezing." Once an ice crystal is formed within a cloud it will grow as cloud droplets around it evaporate and add their mass to the ice crystal eventually forming a snowflake (diffusional growth). Ice crystals can also gain mass as they fall and contact then freeze other supercooled cloud droplets, a process known as "riming." These snowflakes may fall to ground as snow if temperatures at the surface are 0^0 C or colder. They may reach the surface as raindrops if surface temperatures are warmer than freezing.

Research conducted in the late 1940's demonstrated that tiny particles of silver iodide could mimic Mother Nature and serve as freezing nuclei at temperatures colder than about -5^0 C. In fact, these silver iodide particles were shown to be much more active at temperatures of ~ -5^0 to $-15^{0\ C}$ than the natural freezing nuclei found in the atmosphere. As a consequence most of man's modern day attempts to modify clouds to produce more

precipitation (or reduce hail) have used silver iodide as a seeding agent. By definition, these programs are conducted to affect colder portions of clouds; typically cloud regions that are -5^0 C or colder (e.g., "cold clouds"). These programs are sometimes called cold cloud or glaciogenic seeding programs. Glaciogenic cloud seeding can be conducted in summertime clouds by seeding clouds whose tops pass through the -5^0 C level and winter stratiform clouds that reach at least the -5^0 C level.

There has been some research and operational programs designed to increase precipitation from "warm clouds." The seeding agents used in these programs are hygroscopic (water attracting) particles typically some kind of salt (e.g., calcium chloride). These salt particles can form additional cloud droplets, which may add to the rainfall reaching the ground. This seeding technique which is sometimes referred to as warm cloud or hygroscopic seeding can also modify the warm portion of clouds that then grow to reach temperatures colder than freezing. A research program conducted in South Africa targeting these types of clouds indicated that such seeding did increase the amount of rainfall from the seeded clouds.

Summary

Most present day cloud seeding programs introduce a seeding agent, such as microscopic sized silver iodide particles, into clouds whose temperatures are colder than freezing. These silver iodide particles can cause cloud droplets to freeze forming ice crystals. These ice crystals can grow to snowflake sizes falling to the ground as snow or as rain depending on whether the surface temperature is below or above freezing.